203. 40884X00

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TITLE OF THE INVENTION:

FUEL INJECTOR

BACKGROUND OF THE INVENTION

5   <Field of the Invention>

The present invention relates to a fuel injector for

use in an internal combustion engine.

<Prior Art>

Fuel injectors for use in an in-cylinder injection type

10   engine include a device that is one so designed as to ensure that, as set

forth in Japanese Application Patent Laid-Open Publication

No. Hei 11-159421, the marginal portions of the fuel

injection hole exit form an oblique plane not transverse vertical to

the body axial line of the fuel injector, that the restraint

15   force for restraining the flow of the fuel in the radial

direction of the injection hole changes in a

circumferential direction, and that the spraying reach of

the fuel spray which has been injected from injection hole

marginal portions having a small in the restraint force is long and

20   the spraying reach of the fuel spray which has been injected from

injection hole marginal portions having a large in the restraint

force is short. In this case, spray the is stabilized and

the fuel is supplied in the direction of the ignition plug,

with the result that the stability of stratified combustion

25   is ensured.

In the injection of [a] fuel for [its] *producing a* homogeneous combustion, it is important for the injected fuel to be sufficiently mixed with air during the period up to ignition. To achieve this, therefore, there arises the

5   need for the distribution of *the* flow rate to be adjustable between the fuel sprayed towards the ignition plug of the combustion chamber after being injected, and the fuel sprayed towards the piston.

The fuel injectors in prior art, however, are intended

10   to improve combustion stability by making it easy for the fuel to reach the ignition plugs principally during stratified combustion, and no [such] fuel injectors [are] *have been known heretofore* [described] that are designed so that the flow rate distribution ratio of the fuel injected and sprayed for

15   the air intake stroke occurring during homogeneous combustion differs between fuel spraying towards the piston and fuel spraying towards the ignition plug.

SUMMARY OF THE INVENTION

20   The object of the present invention is to [supply] *provide* a fuel injector by which spraying patterns *that are* different in flow rate distribution ratio can be formed to accelerate the mixing of a sprayed fuel with air and thus to improve the stability of homogeneous combustion.

25   A difference between the flow rate distribution ratio

of the fuel sprayed towards the pistons and that of the

fuel sprayed towards the ignition plugs can be generated

by providing, downstream with respect to and outside the

injection hole of the fuel injector, a flow restraint means

5 for restraining the flow of the fuel, [and making said] which flow

restraint means operates to restrain the flow of the fuel in at least

two places so as to split the injected fuel into portions

high in spraying density and portions low in spraying

density and so as to generate a difference in quantity

10 between the split portions high in spraying density.

The flow restraint means described above can be

implemented by providing, (in) almost parallel to the

above-mentioned injection hole, a wall surface for

restraining the flow of the fuel in its radial direction,

15 or by providing (in), almost parallel to the central axis of

the injection hole, a plurality of wall surfaces for

limiting the flow of the injected fuel. The formation of

these wall surfaces enables the creation of a plurality

of restraint areas in which the flow of the fuel in (its) the

20 radial direction or in its flow direction is to be

restrained, and a plurality of release areas in which the

fuel can flow in (its) the radial direction.

In a fuel injector for use in an in-cylinder injection

type internal-combustion engine, it becomes possible, by

25 assigning a different size to the multiple release areas

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mentioned above, to form spraying patterns [so] that during

the spraying of the fuel injected from the injection hole,

the density distribution of the sprayed fuel at a cross

section [vertical] to the body axial line of the fuel injector

5   concentrates in approximately two directions, and [so] that

the spraying pattern of the fuel is set to ensure that the

flow rate of the sprayed fuel in one of the two directions

of concentration is greater than the flow rate of the fuel

in the other direction.

10   As a result, according to the fuel injector of the

present invention, spraying [into] a density distribution

asymmetrical to the injection hole axis can be formed and

when this fuel injector is used in an in-cylinder type of

internal-combustion engine, the flow rate distribution

15   ratios of the fuel sprayed towards the ignition plug of

the engine and the fuel sprayed towards the piston can

be optimized according to [the] particular mixing ratio of

the fuel and air.

20   BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view showing an embodiment

of the fuel injector pertaining to the present invention;

FIG. 2 is an enlarged cross-sectional view [of] the

neighborhood of the injection hole in the fuel injector

25   pertaining to the present invention;

FIG. 3 is a front view of the neighborhood of the

injection hole in the fuel injector when seen from the

direction of arrow III in FIG. 2;

FIG. 4 is a further enlarged front view of the

neighborhood of the injection hole shown in FIG. 3

(cross-hatching denotes the bump portion in the frontal

direction of the paper surface);

FIG. 5 is an enlarged view of the neighborhood of the

injection hole in another embodiment of the fuel injector

having fuel flow restraint means as wall surfaces

(cross-hatching denotes the bump portion in the frontal

direction of the paper surface);

FIG. 6 is an enlarged view of the neighborhood of the

injection hole in the fuel injector shown in FIG. 4, and

showing an embodiment in which the means for restraining

the flow of fuel in a radial direction is provided as an

extension to the injection hole (cross-hatching denotes

the bump portion in the frontal direction of the paper

surface);

FIG. 7 is a cross-sectional view showing epitomically

the spraying pattern obtained by using the fuel injector

of the present invention;

FIG. 8 is a cross-sectional view showing an embodiment

in which the fuel injector pertaining to the present

invention is mounted in the cylinder of an internal-combustion engine;

FIG. 9 (a) is a cross-sectional view and (b) is a front view showing an embodiment of the fuel injector pertaining to the present invention;

FIG. 10 is a [further enlarged] diagrammatic view of the neighborhood

5   of the injection hole in the fuel injector shown in FIG. 9;

FIG. 11 is [an enlarged front] a diagrammatic view showing the neighborhood of the injection hole in an embodiment of a fuel injector having a function equivalent to that of the

10   fuel injector shown in FIG. 5 (cross-hatching denotes the bump portion in the frontal direction of the paper surface); and

FIG. 12 is a cross-sectional view showing the spraying status of [a] fuel.

15

DESCRIPTION OF THE INVENTION:

FIG. 1 is a cross-sectional view showing the structure of an embodiment of the fuel injector pertaining to the present invention. The fuel injector shown in FIG. 1 is a

20   normally closed type of electromagnetic fuel injector, in which a valve body 102 and seat portion 202 are in firm contact when power is not supplied to a coil 109. [A] Fuel is supplied from a fuel supply port under [the status that] pressure [is assigned] determined by a fuel pump (not shown in the figure), so that

25   [and] the fuel passageway 106 of the fuel injector is filled

to injection hole central axis 200, and a⟨second⟩ line segment [routing]⟨passing⟩ through the center of injection hole 101 and running orthogonally with respect to injection hole central axis 200 and ⟨the first⟩ line segment are shown with a

5   single-dashed line in FIG. 3.

On that plane vertical to ⟨the⟩ injection hole central axis 200 that is present at the open end of injection hole 101, a recess 203 is provided so as to overhang the open end of injection hole 101. Wall surfaces 204a, 204b, 205a, and

10   205b parallel to injection hole central axis 200 are formed at the open end of the injection hole by recess 203. The distance between wall surfaces 204a and 205a is set so as to be shorter than the distance between wall surfaces 204b and 205b.

15   FIG. 4 is a further enlarged view of the injection hole open end shown in FIG. 3, and it is a view of the neighborhood of ⟨the⟩ injection hole, showing the way the fuel is injected from the injection hole. The cross-hatched portion in this view has the shape of a bump relative to recess 203.

20   The wall surface in the area from point 405 to point 406 and the wall surface in the area from point 407 to point 404 are provided outside the inner wall 201 of the injection hole in the radial direction thereof. This arrangement of wall surfaces enables the open end of the injection hole

25   to be machined accurately and easily since, after the wall

surfaces located in parallel with injection hole central
axis 200, ↗that are↖downstream with respect to injection hole 101,
have been machined, when the injection hole is machined
from the upstream end thereof using a punch or the like,

5   members can be applied between the inner wall of the
injection hole, the wall surface in the area from point
405 to point 406, and the wall surface in the area from
point 407 to point 404.

    The fuel injector shown in FIGS. 1 to 4 is an example

10   of a swirl-type fuel injector in which the wall surfaces
parallel to↗the↖injection hole central axis 200, shown in the
areas from point 405 to point 406 and from point 407 to
point 404, are provided downstream with respect to and
outside↗of↖the injection hole as a means for restraining the

15   radial flow of the fuel.

    The fuel injector shown in FIGS. 1 to 4 is a swirl-type
fuel injector in which the fuel is rotationally injected
from injection hole 101. The pressure near the center of
injection hole 101 is reduced by the rotation of the fuel,

20   and the fuel rotates into↗a sheet↖membrane form [and]↗as it↖flows downward
along↗the↖injection hole inner wall 201. Accordingly, the fuel
is injected from the outer surface of↗the↖injection hole inner
wall 201[,] with [the]↗a↖velocity corresponding to [the]↗a↖component
in the tangential direction of inner wall 201 (namely, [the]↗a↖

25   component in the rotational direction of the fuel) and [the]↗a↖

velocity corresponding to [the] component in the downward

direction of injection hole central axis 200. Arrow 403

in FIG. [3] signifies the rotational direction of the fuel,

and arrows 408 to 412 denote the direction of fuel

injection.

Of all wall surfaces parallel to injection hole central

axis 200, only those existing in the areas from point 405

to 406 and from point 407 to point 404 [are] restraint wall

surfaces at which the flow of the fuel in the radial

direction of the injection hole is restrained. Since the

fuel continues rotating at these restraint wall surfaces,

the quantity of fuel injection at the restraint wall

surfaces decreases in comparison with the quantity of fuel

injection in the area where the flow of the fuel in the

radial direction of the injection hole is not restrained.

When the walls are tall enough, in particular, almost no

fuel is injected from the areas from point 405 to 406 and

from point 407 to point 404.

The quantity of fuel injection at the restraint wall

surfaces is determined by the ratio between the velocity

of the fuel in its rotational direction and the velocity

in the direction of the injection hole central axis, and

the height of the restraint walls. For example, if the

height of the restraint walls is greater than the distance

through which the fuel flows in the direction of the

injection hole central axis while rotating in the area from point 405 to point 406, almost no fuel is injected from the area from point 405 to 406.

In the areas from point 404 to point 405 and from point 406 to point 407, however, since the flow of the fuel in the radial direction of the injection hole is not restrained, a large portion of the fuel is injected from these areas.

Since the spread [of spraying] of the fuel after it has been injected is [almost] determined by the size of the release areas in which the flow of the fuel in the radial direction of the injection hole is not restrained, the flow rates of the fuel injected from point 404 to point 405 and from point 406 to point 407 can be adjusted by varying the dimensional ratio of these areas.

Here, to ensure that the fuel that has been injected from the release areas mentioned above forms a uniform spraying pattern, it is desirable that the relationship in position between points 406 and 407 that determines the release area in which the flow rate of the fuel injected is greater should be such that the angle in the area from point 406 to point 407 with injection hole central axis 200 as its center is 180 degrees or greater. The reason for this is that when the distances between points 405 and 406 and between points 407 and 404 in the restraint areas

of flow of the fuel in the radial direction of the injection

hole are long enough, since the quantities of fuel

rotationally flowing out along these wall surfaces will

increase and these quantities of fuel will flow out from

5   the starting points of the release areas (namely, points

406 and 404), the density of the fuel flowing out from these

points will increase and the density distribution of the

sprayed fuel will tend to be non-uniform.

When the requirement is satisfied that the

10   relationship in position between points 406 and 407, that

determines the release area in which the flow rate of the

fuel injected is greater, should be such that the angle in

the area from point 406 to point 407, with injection hole

central axis 200 as its center, is 180 degrees or greater,

15   it becomes possible to reduce the circumferential length

of the wall surfaces at which the (flow of the) fuel flows in the

radial direction of the injection hole, to control the

quantities of fuel flowing out from the starting points

of the release areas (namely, points 404 and 406), and to

20   achieve almost uniform spraying of the fuel injected from

the release areas.

As described above, the fuel injected from points 406

and 404 acts to increase the spraying density, and it is

known that the reach of the fuel spray after being

25   injected becomes long at this section.   If the reach of the

fuel spray needs to be even longer according to the particular specifications of the engine, the section where these sprays of fuel concentrate can be intentionally created for partially increased reach of the fuel spray.

5   In this case, the areas from point 405 to point 406 and from point 407 to point 404, that is to say, the areas where the flow of the fuel in the radial direction of the injection hole is restrained, should be extended or the height of the wall surfaces in these areas should be increased.

10   In the fuel injector shown in FIGS. 1 to 4, the uniformity of the fuel spray can be changed according to the particular size of the areas in which the flow of the fuel in the radial direction of the injection hole is released. When it is desirable that the fuel be

15   particularly uniform, however, it is possible to split fuel spraying into approximately two directions by adopting such a structure as shown in FIG. 5, and make the quantities of split fuel spray different from each other, while at the same time making each split spray pattern uniform.

20   FIG. 5 shows an example in which wall surfaces 501 and 502 almost parallel to the central axis 200 of the injection hole are provided downstream with respect to and outside of this injection hole as fuel flow restraint means, and this figure is a front view of the fuel flow restraint means when seen

25   from the open end of the injection hole. Wall surfaces 501

and 502 are provided at a point where they come into contact with the fuel after it has been injected following downward flow along injection hole inner wall 201.

The maximum value of the distance Cw between the injection hole inner wall 201 and the wall surface 501 that brings wall surface 501 and the injected fuel into contact is determined by the ratio between the velocity Vt of the fuel in its rotational direction and the velocity Va of the fuel in the direction of the injection hole central axis, and the height Hw of the restraint walls. In other words, Cw needs to be smaller than at least Hw × Vt/Va. The value of Vt/Va, which is the ratio between the velocity Vt of the fuel in its rotational direction and the velocity Va of the fuel in the direction of the injection hole central axis, can also be estimated from the spread angle θ of the fuel spray, and this relationship can be represented as tanθ = Vt/Va.

Here, the spread angle θ of the fuel spray is the angle θ at which the fuel that has been injected from the injection hole spreads in the direction of departure from the central axis 200 of the injection hole. FIG. 12 is a cross-sectional view showing the way the fuel is injected from the open end of the injection hole as seen along line IV-IV in the fuel injector of FIG. 5 is shown in IV-IV' cross-sectional form. In actual operation, it is possible to photograph the cross

section of the fuel spray as shown in FIG. 12, by radiating
sheet-like light (such as a laser beam) onto the sprayed fuel
so as to pass through the central axis 200 of the injection
hole, and photographing the fuel spray pattern, thereby making it possible
5   to measure the spread angle θ of the fuel spray.

In the fuel injector of FIG. 5, the fuel that has flows
downstream while rotating along the injection hole inner wall
201 is injected in the directions of arrows 511 to 516 at
the open end of the injection hole. At this time, portions
10 of the wall surfaces 501 and 502, functioning as a fuel flow
restraint means, interfere with the injected fuel, with
the result that the fuel does not splash in its intended
direction.

The fuel that has been injected in the direction of
15 arrow 511 in, for example, FIG. 5 splashes without
interference between the fuel and wall surface 502, since
and the point of interception
the distance L between the injection point 511a of arrow
511 with the wall surface 502 is sufficiently long. However,
the fuel that has been injected in the directions of arrows
20 512 and 513 interferes with the wall surface 502 and does not
splash in the intended direction, because the distance
between injection points 512a and 513a and wall surface
502 is too short.

Likewise, the fuel in the direction of arrow 515
is intercepted by the
25 interferes with the wall surface 501 and does not splash in

the intended direction.

In this way, the presence of wall surfaces 501 and 502
as the fuel flow restraint means causes interference
between the fuel and the wall surfaces, resulting in such
distribution-of-spraying as shown in FIG. 6.

Also, such shape of the injection hole open end as shown
in FIG. 11 can be used to obtain results similar to those
of FIG. 5. In FIG. 11, wall surfaces 501' and 502' parallel
to the central axis of the injection hole are provided as
a means for restraining the flow of the fuel after it has
been injected. The restraint areas where the flow of the
fuel is restrained and the release areas where the flow
of the fuel is not restrained can be adjusted according
to the particular relationship in position between
injection hole inner wall 201 and wall surfaces 501' and
502'.

The fuel release areas α and β in FIG. 11 are determined
by the distance L from the injection point of the fuel,
the height Hw of wall surfaces 501' and 502', the velocity
component Vt of the fuel in its rotational direction, and
the velocity component Va of the fuel in the direction of
the injection hole central axis.

The injection point 1102 on injection hole inner wall
201 shown in FIG. 11 is a point located exactly at the
boundaries of the release areas and the restraint areas,

and the fuel that has been injected from the injection

points located in the direction of area β from this point

does not come to interfere with wall surface 502'.

Injection point 1101 is also located at the boundaries of

5   the release area and the restraint area, and the fuel

that has been injected from the injection points located

in the direction of area α from this point does not come

to interfere with wall surface 501'.

At these injection points located at the boundaries,

10   the relationship in position between the wall surface and

the injection point is determined by the distance L from

the injection point of the fuel, the height Hw of wall

surfaces 501' and 502', the velocity component Vt of the

fuel in its rotational direction, and the velocity

15   component Va of the fuel in the direction of the injection

hole central axis, and this relationship can be represented

as $L = Hw \times Vt/Va$.

Injection points 1103 and 1104 are also points located

at the boundaries of the release areas and the restraint

20   areas. These injection points located at the boundaries

become tangent points when a tangent line is drawn from

the positions closest to the injection hole inner wall 201

among all points on the wall surfaces 501a and 502a (in FIG.

11, these positions are shown as points 1107 and 1108),

25   to the injection hole inner wall.

In this way, the four boundaries between the release areas and the restraint areas can be adjusted according to the particular relationship in position between wall surface 501', wall surface 502', and injection hole inner

5   wall 201, and the particular height of wall surfaces 501' and 502'. As a result of this, the respective sizes of the release areas and the restraint areas can be adjusted. For example, increasing the height of wall surfaces 501' and 502' narrows the release areas. Conversely, distancing

10   wall surfaces 501' and 502' from the injection hole inner wall broadens the release areas.

FIG. 6 is a view of the open end of the fuel injector in which portions of the wall surfaces 205b, 205a, 204a, and 204b that are parallel to injection hole central axis

15   200 in FIG. 2 come into contact with the injection hole inner wall and form a portion thereof. That is to say, in FIG. 6, the length of injection hole inner wall 201' in the direction of the central axis 200 of the injection hole is made different from the length of the injection hole

20   in its circumferential direction. In the areas from point 601 to point 602 and from point 603 to point 604, the injection hole inner wall is longer as it goes in the direction of injection hole central axis 200 (that is to say, the longitudinal direction with respect to the paper

25   surface of FIG. 6), and functions as a means for restraining

the flow of the fuel in its radial direction. In the areas from point 601 to point 603 and from point 602 to point 604, the injection hole inner wall is shorter as it goes in the direction of injection hole central axis 200[,] and

5 forms a release area in which the flow of the fuel in its radial direction is not restrained.

Here, the area from point 601 to point 603 as the serving release area, and the area from point 602 to point 604 differ in spread. More specifically, a plurality of areas at

10 which the length of the injection hole inner wall 201' in the direction of the injection hole central axis 200 is short are provided in the circumferential direction of the injection hole to ensure that circumferential areas shorter in the length of injection hole inner wall 201' in the direction

15 of injection hole central axis 200 differ from each other in spread.

The use of a fuel injector [of such] having a configuration as shown in FIG. 6 produces results similar to those obtained from the use of a fuel injector having [such shape of the] an with a shape

20 injection hole open end, as shown in FIG. 3. Under such a configuration, [such] the shape of the injection hole open end carrying out as shown in FIG. 6 can be easily obtained by [conducting] cutting operations, near-net-shave plastic working operations, and/or the like, on a general fuel injector

25 whose injection hole open end is not provided with any wall

surfaces parallel to the injection hole central axis 200.

FIG. 7 is an epitomic view of the spraying pattern formed by the fuel which is injected by the fuel injector of FIGS. 1 to 6. This figure shows the spraying pattern as seen downstream with respect to the fuel injector, and this spraying pattern exhibits a cross section within a plane perpendicular to the central axis of the injection hole.

All fuel injectors shown in FIGS. 1 to 6 have a fuel flow restraint means, which restrains the flow of the fuel in at least two places, and since the sizes of the fuel flow restraint areas differ at each place, the distribution shape of the spray at a cross section perpendicular to the injection hole central axis 200 is split into approximately two directions (701 and 702), as shown in FIG. 7, and at the same time, the respective quantities-of-distribution and spreads of the spray take different shapes.

The distribution shape of the spray can be changed according to the particular spread of the release areas in which the flow of the fuel is not restrained.

More specifically, in the fuel injector of FIG. 4, the distribution shape of the spray can be changed by varying the height Hw (shown in FIG. 2) of the wall surfaces parallel to the injection hole central axis 200, and the respective widths (Wa and Wb in FIG. 4). For example, if height Hw

of the wall surfaces is increased, the spread of spray
will be narrower since the effectiveness of the wall
surfaces at which the flow of the fuel in its radial
direction is to be restrained will increase for the fuel

5   that rotationally flows. It is also possible, by varying
Wa and Wb, to change the spread of the release areas at
which the flow of the fuel in its radial direction is not
to be restrained, and thereby to adjust the flow rate
distribution of the approximately bi-directionally split

10   sprays of fuel in the respective directions.

FIG. 8 is a cross-sectional view showing the internal
situation of an engine cylinder existing when the fuel
injector having the injection hole open end shown in FIGS.
1 to 5 was installed at the air intake valve end of an

15   in-cylinder injection engine equipped with two intake
valves and two exhaust valves and fuel was injected into
the combustion chamber during intake stroke. Since the
injection is conducted during the intake stroke, intake
valve 803 is in an open status during fuel injection. It

20   is advisable that the fuel injector be installed so that
of the flow rate concentration portions of spray during
which the flow rate of the fuel concentrates in
approximately two directions, only the portion smaller in
flow rate flows towards ignition plug 802 and the portion

25   larger in flow rate flows towards piston 804.

By installing the fuel injector in this way [and]

injecting the fuel, since spray is split into the

direction of piston 804 underneath intake valve 803 and

the upward direction of intake valve 803, the fuel density

distribution of the mixture inside the cylinder during

ignition can be prevented from becoming too lean, or the

fuel density distribution of the mixture at the side of

piston 804 can be prevented from becoming too dense. If

the fuel density near ignition plug 802 is too low or too

high, [these can cause] a misfire, namely, failure in the

firing of the mixture. Spraying in the direction of

ignition plug 802 is therefore effective for preventing

a misfire and for suppressing reduced engine output and

the emission of an unburned fuel.

The effectiveness described above can be obtained only

by providing a fuel flow restraint means downstream with

respect to the injection hole, and this is not limited to

the shapes of the injection hole open ends shown as examples

in FIGS. 3, 4, and 5. The above effectiveness can also be

obtained in a fuel injector having the shapes of the

injection hole open ends shown in, for example, FIGS. 9(a), 9(b)

and 10. Even for the shapes of the injection hole open ends

shown in FIGS. 9(a), 9(b) and 10, two areas in which the flow of

the fuel in the radial direction of the injection hole is

not restrained are provided in the circumferential

direction of the injection hole, downstream with respect to the open end thereof, and these areas are provided so as to differ from one another in size. Because of this configuration, the distribution of the spraying at a cross

5 section [vertical] perpendicular to the injection hole axis 200 of the injected spray of fuel concentrates in approximately two directions, and spraying can be set to a pattern in which one of the two sprays of fuel is larger in flow rate and the other is smaller in flow rate.

10 The shapes of the injection hole open ends shown in FIGS. 9(a), 9(b) and 10 are also effective in that, when the fuel injector is mounted in an in-cylinder injection engine, changes in the spraying direction and spraying density of the fuel due to the creation of deposits during the

15 carbonization of the fuel and lubricants are reduced.

FIG. 10 is a further enlarged view of the injection hole open end shown in FIG. 9(b), and this view also shows above-mentioned deposits 1003 (903) and 904 which, with respect to the entire injection hole open end, are provided on only the recessed wall surfaces

20 205b" and 205a" at the upstream side with respect to the flow (rotational) direction of the fuel.

For the shape of the injection hole open end shown in FIG. 9(b), the angle at the corner 1005 905 where the above-mentioned recessed wall surface 205a" at the upstream side

25 and wall surface 204b" are connected, is acute, and the angle

at the corner 906, where wall surface 205b" and wall surface 204a" are connected, is approximately perpendicular. Both the wall surface 205a" connected to corner 905 and wall surface 205b" connected to corner 906 are positioned at a location

5   where they do not interfere with the injected fuel, and so deposits easily accumulate on these wall surface surfaces when the engine is operated. In the case of the injection hole open end shown in FIG. 3 (4), wall surfaces 205b and 205a correspond to the wall surfaces 205b" and 205a",

10   respectively, in FIG. 10. In the case of the injection hole open end shown in FIG. 3 (4), if deposits stick to wall surfaces 205b and 205a, since these deposits will accumulate and grow in the approximately perpendicular direction of wall surfaces 205b and 205a, the deposits will easily interfere

15   with the injected fuel. Therefore, by forming the corners between wall surfaces 205b" and 204a" and between wall surfaces 205a" and 204b" into either an approximately perpendicular or acute angle, as shown in FIG. 10, the deposits that accumulate on wall surfaces 205b" and 205a"

20   can be prevented from easily interfering with the fuel that splashes, and, as a result, changes in the spraying pattern due to the growth of the deposits can be suppressed.

The shapes of the injection hole open ends shown in FIGS. 9 (a), 9(b) and 10 are designed so that even if the shapes of

25   these open ends are formed by plastic working, the desired

spraying pattern can be obtained. For the shapes of the
injection hole open ends shown in FIGS. 9 (a), 9(b) and 10, wall
surfaces 204a" and 204b" located downstream with respect
to the flow (rotational) direction of the fuel are formed

5   in the an approximately tangential direction of the
circumference of the injection hole inner wall 201, at the
position closest to inner wall 201.

Wall surfaces 204a" and 204b" located downstream with
respect to the rotational direction of the fuel in FIG.

10   10 correspond to the wall surfaces 204a and 204b in FIG.
4. As with wall surface 204a, however, wall surface 204a
is not formed in the an approximately tangential direction
of the circumference of injection hole inner wall 201, at
the position closest to inner wall 201, and has an angle.

15   In general, when an injection hole open end is formed
by plastic working, since corners are not easy to work,
it is easier to provide radial portions having a curvature.
However, at wall surfaces, such as wall surface 204a, that
affect the spraying pattern because of interference with

20   the fuel that splashes, since the presence of radial
portions changes the distance with respect to the fuel
injection positions on the outer periphery of the injection
hole inner wall 201, the degree of interference with the
fuel that splashes differs according to the particular

25   dimensions of the radial portions. For this reason,

factors, such as dimensional differences associated with the manufacture of the radial portions, may cause the spray pattern to vary from fuel injector to fuel injector.

5   Hence, [by forming] as shown in FIG. 10, [wall surfaces 204a" and 204b" in [the] approximately tangential direction of the circumference of injection hole inner wall 201, at the position closest to inner wall 201, it becomes unnecessary to provide corners at the wall surfaces that

10   affect the spray pattern because of interference with the fuel that splashes, and it also becomes possible to obtain a fuel injector creating the desired spray pattern, even when the injection hole open end is processed using a processing method, such as plastic working, that

15   facilitates the manufacture of this open end by providing a curvature at each corner.

As set forth above, according to the present invention, a fuel injector that enables the flow rate of a sprayed fuel to be concentrated into approximately two directions

20   by use of a relatively simple method and [makes] differences between the respective flow rate distributions, can be supplied by processing the injection hole open end of a swirl-type fuel injector equipped with a single injection hole, and then providing in the circumferential area of

25   the open end of the injection hole a plurality of release

areas different in size and in which the fuel can flow
radially. The effectiveness described above can be
achieved by changing the shape of the injection hole open
end, and thus, since new parts do not need to be added, a

5 fuel injector appropriate for the particular
specifications of the in-cylinder injection engine can be
supplied without any significant increase in costs.

According to the fuel injector pertaining to the
present invention, an ideal spraying pattern for the

10 intended in-cylinder injection engine can be obtained.